e^-e^+ Sources for Linear Colliders

Tuesday, July 15, 2003

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e^-e^+ Sources

- Polarized Electron Sources
- Conventional Positron Sources
- Undulator Based Positron Source

NLC, TESLA, CLIC Parameters

Parameters	CLIC	NLC/GLC	TESLA	Units
n_b	0.63	0.8	2.3	$\times 10^{10}$ $e^-(e^+)$
T_b	0.67	1.4	337	ns
N_b	154	192	2820	#/train
F_{rep}	200	120/150	5	Hz
$\gamma\varepsilon$	7	100	40	$\times 10^{-6}$ m-rad
Δz_{FWHM}	7	10	8	mm
$\Delta E/E_{FWHM}$	2	2	1	%
P_{e-}(e^- only)	80	80	80	%

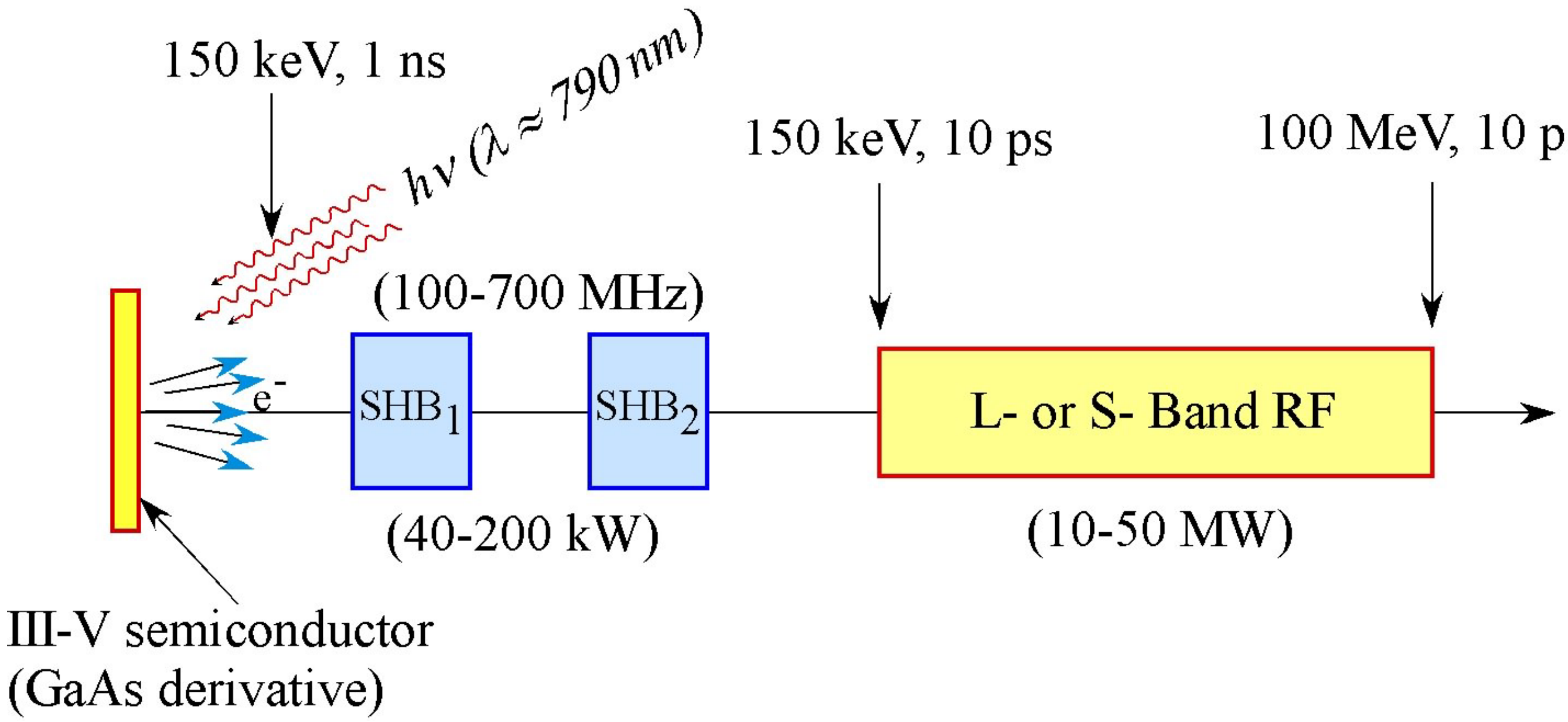
Polarized Electron Sources

At present, all linear collider polarized electron source designs (CLIC, GLC, NLC, TESLA) are based on the SLC polarized electron source: DC gun, GaAs derivative photocathode, 800 nm laser, SHB bunching, damping rings required.

TESLA also includes an unpolarized, low emittance rf gun system, damping rings still required.

Polarized Electron Sources

Generic LC Polarized e⁻ Source



Polarized Electron Sources

[CLIC, NLC/GLC, TESLA]

n_B: 0.42- 2.3 $\times 10^{10}$ e-/bunch

t_b: 0.7 - 337 ns

N_b: 154- 2820 bunches/train

F_{rep}: 200 - 5 Hz

$\gamma\varepsilon$: < 100 m-rad

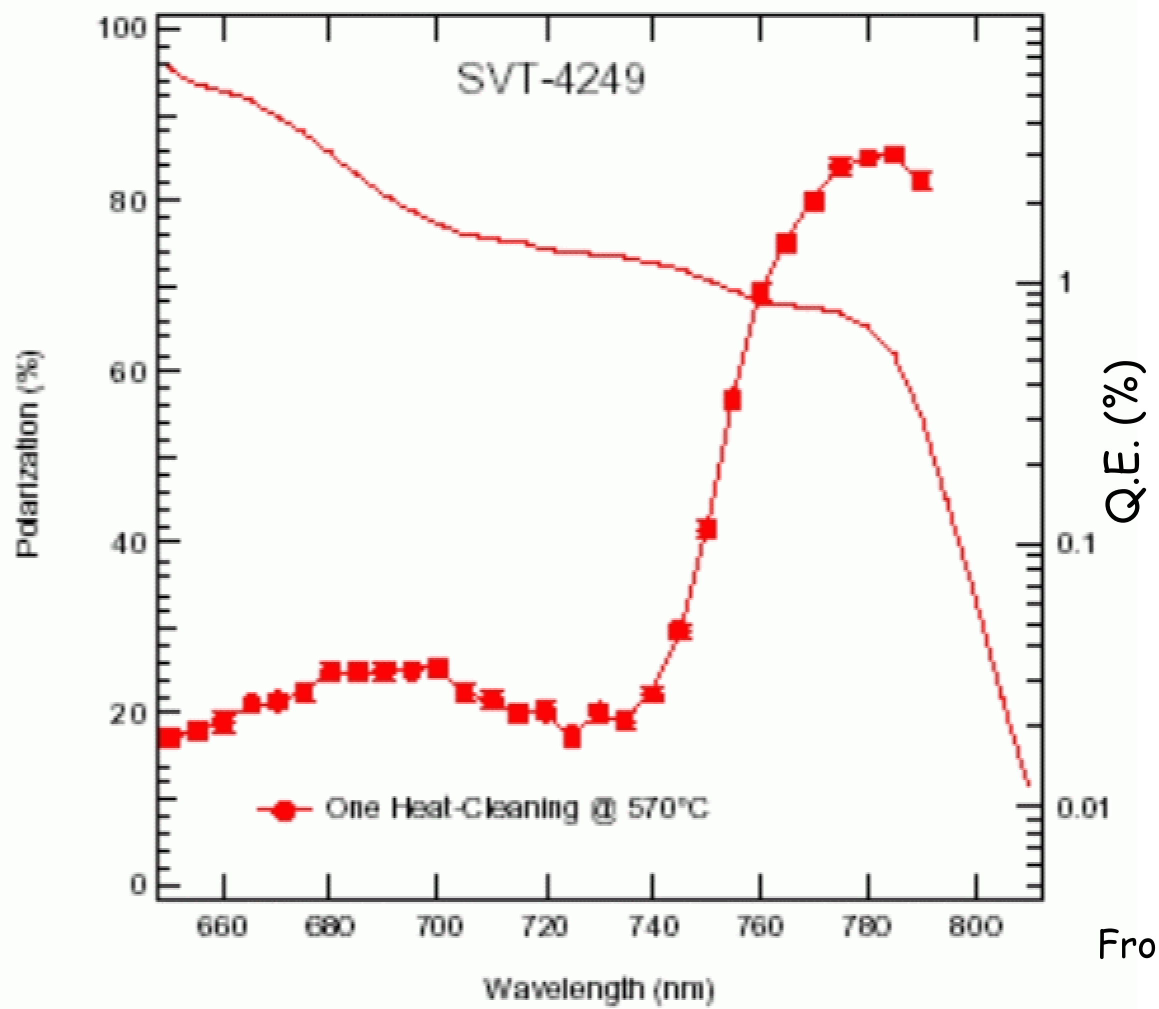
σ_z: < 10 mm

σ_E: ~1%

P_e: > 80%

Polarized Electron Sources

E158-2003: strained, super-lattice, T. Maruyama for PPRC



From M. Woods

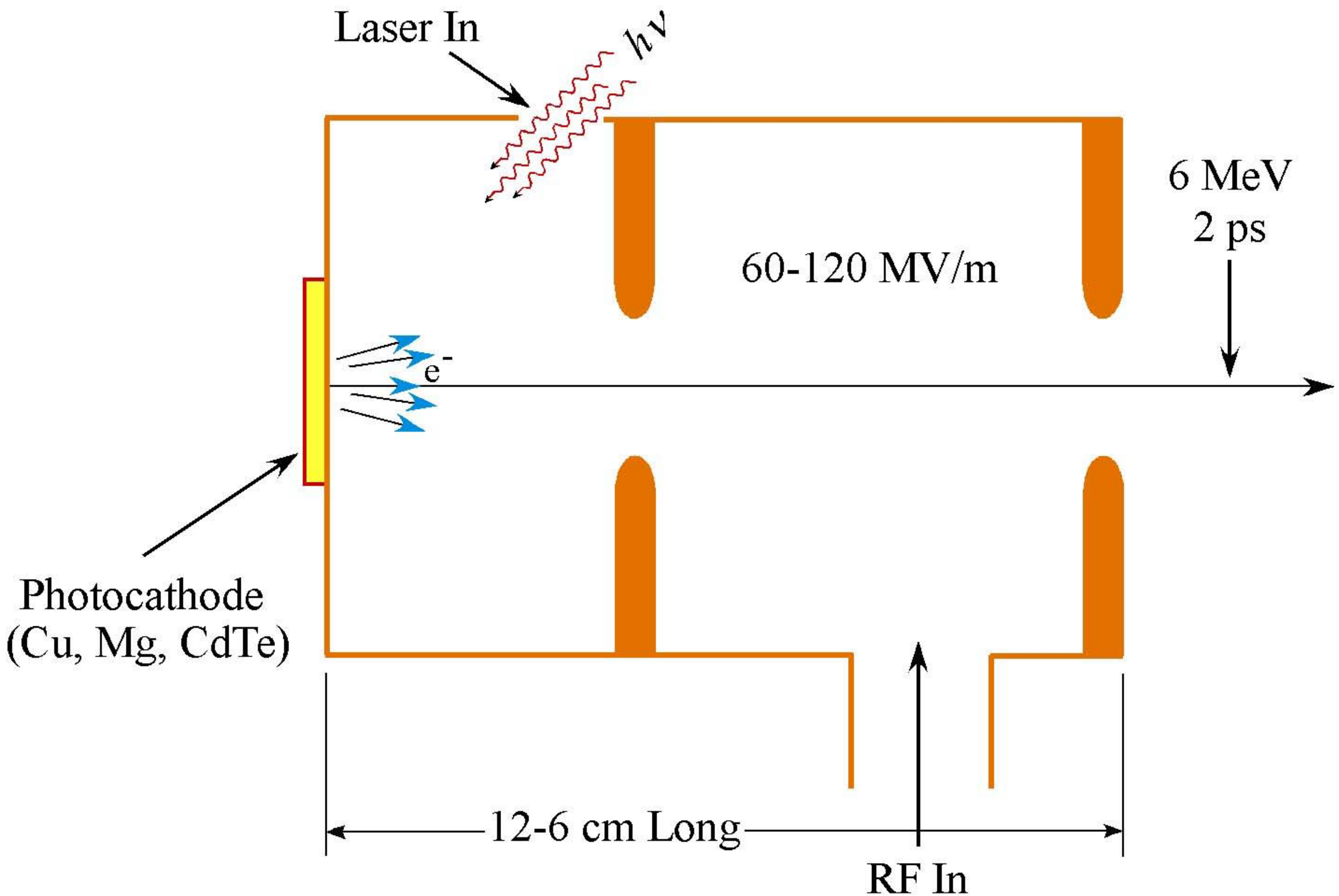
Polarized Electron Sources

NLC Scaled from SLC Polarized e- Source (NLC/GLC, CLIC require essentially the same system(s); TESLA can use SLC-gun design directly but needs different laser)

- HV_{SLC} = 120 kV, HV_{NLC} = 165 kV
- $\langle P_{SLC} \rangle$ = 77%, 1994-96, $\langle P_{SLC} \rangle$ = 74%, 1997-98
- $\langle P_{NLC} \rangle$ = 80%, Specification
- $\langle P_{E158} \rangle$ = 82%, 2002 (~86%, 2003)
- $\langle P_{PPRC} \rangle$ = 90%, Goal (~85% at present)

(200 kV gun in development at Nagoya Univ, Nakanishi et al.)

LC Electron Sources, rf Guns



LC Electron Sources, rf guns

RF Guns: lower emittance, no SHB, no polarization; good for 4^{th} generation light sources (LCLS, TESLA FEL) and test facilities (KEK, TTF, ???); do not meet ALC specifications

NLC Letter of Support for DULY Research Phase II SBIR: PWT RF Gun, Polarized Photocathode; testing to be done at SLAC: Approved July, 2003

TESLA design includes a low emittance, flat beam, rf gun. Unpolarized, emittance goals do not meet damped beam requirements.

LC Electron Sources

Polarized Electron Sources for the various are all very similar and are based on the SLC polarized electron source

Considerable engineering is required to develop the stable, multibunch laser systems (not discussed)

Beam loading in the bunching systems and initial capture section(s) needs consideration

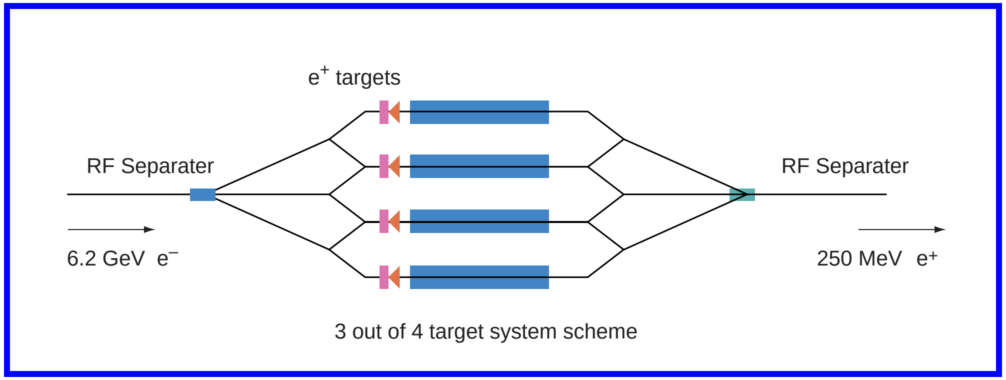
Present rf guns do not meet polarization or emittance specifications

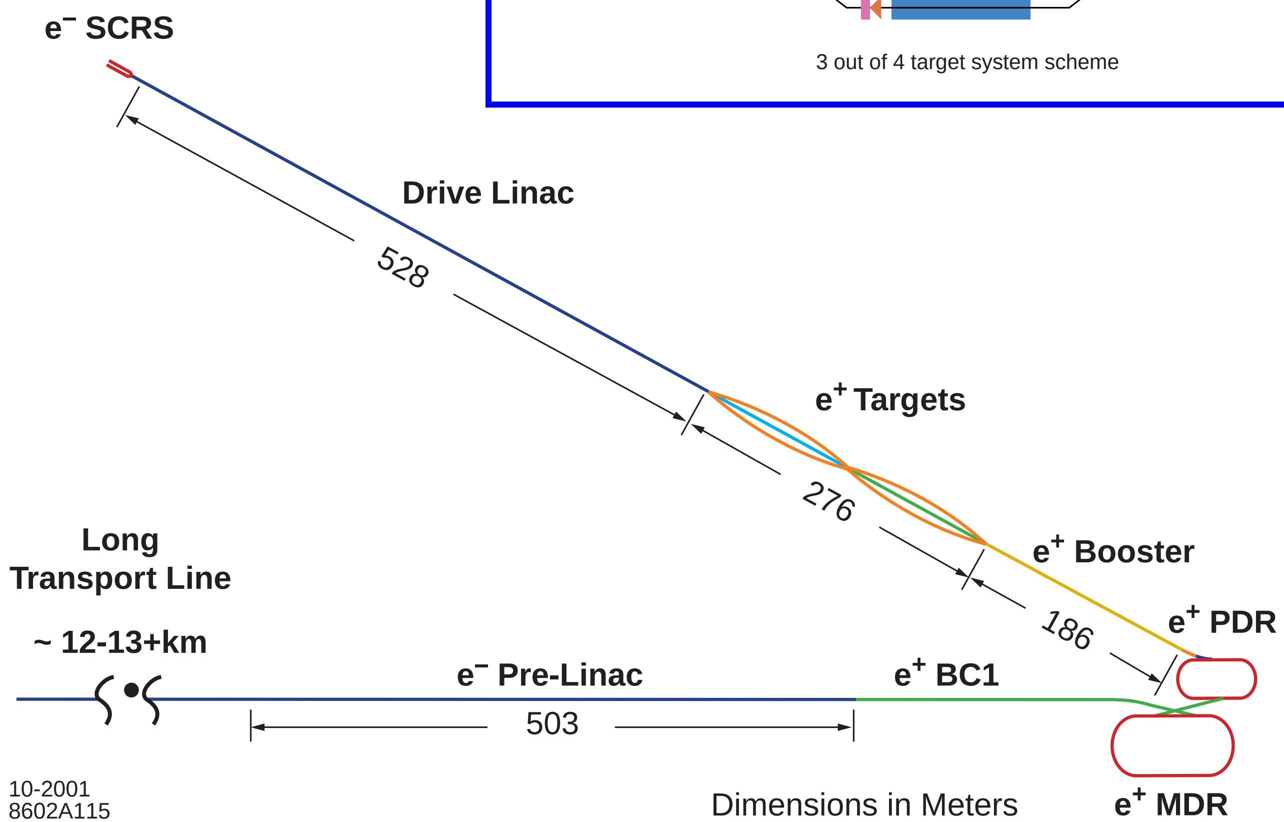
Polarized rf gun development is beginning, unlikely to eliminate DR's

Conventional Positron Sources

Conventional Positron System: Multi-GeV electron beam incident to a thick, high Z target. System is followed by an SLC-like adiabatic matching device (flux concentrator of ~ 6-7 T peak field) and a high gradient L-band capture section for acceleration to 250 MeV, solenoidal focusing, followed by a L-band linac with quadrupole focusing

NLC Conventional e^+ Source





Conventional Positron Sources

Issues for Conventional Sources

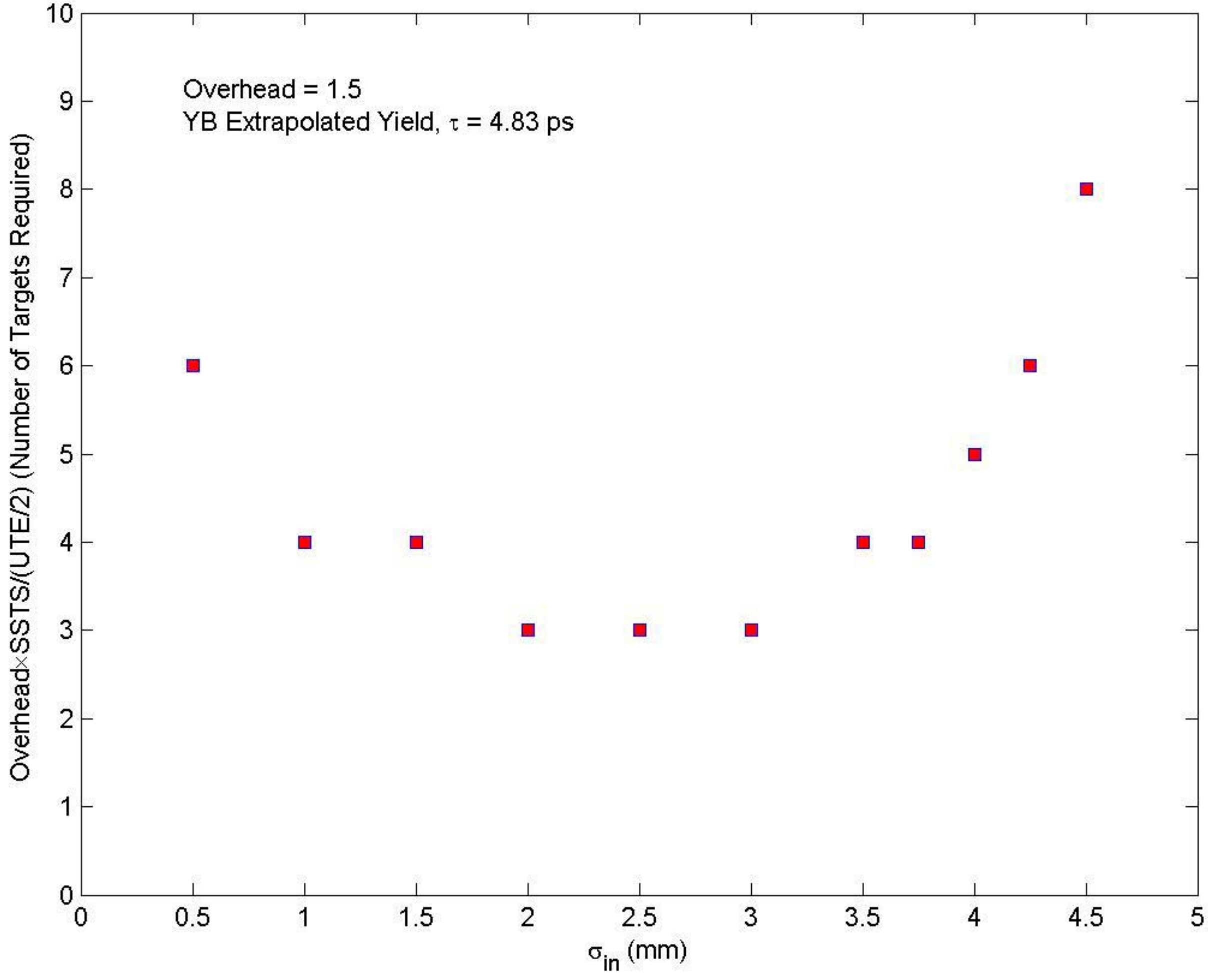
- Peak Energy Deposition (<50 J/g for W-Re alloys)
- Average Power Removal
- Radiation/Mechanical Damage to Targets
- Maintenance/Repair in HiRad Environment

Question: Can one consider developing a conventional e+ source for a TESLA formatted beam?

Answer: Why not. The primary issue is that of the peak shock stress in the target. If acceptable, then there is a considerable amount of optimization to do.

EGS4, BeamPath, MatLab Simulations and Calculations: Number of Targets, UTE(1000^0C) and V_t=100 m/s, r_t = 1 m

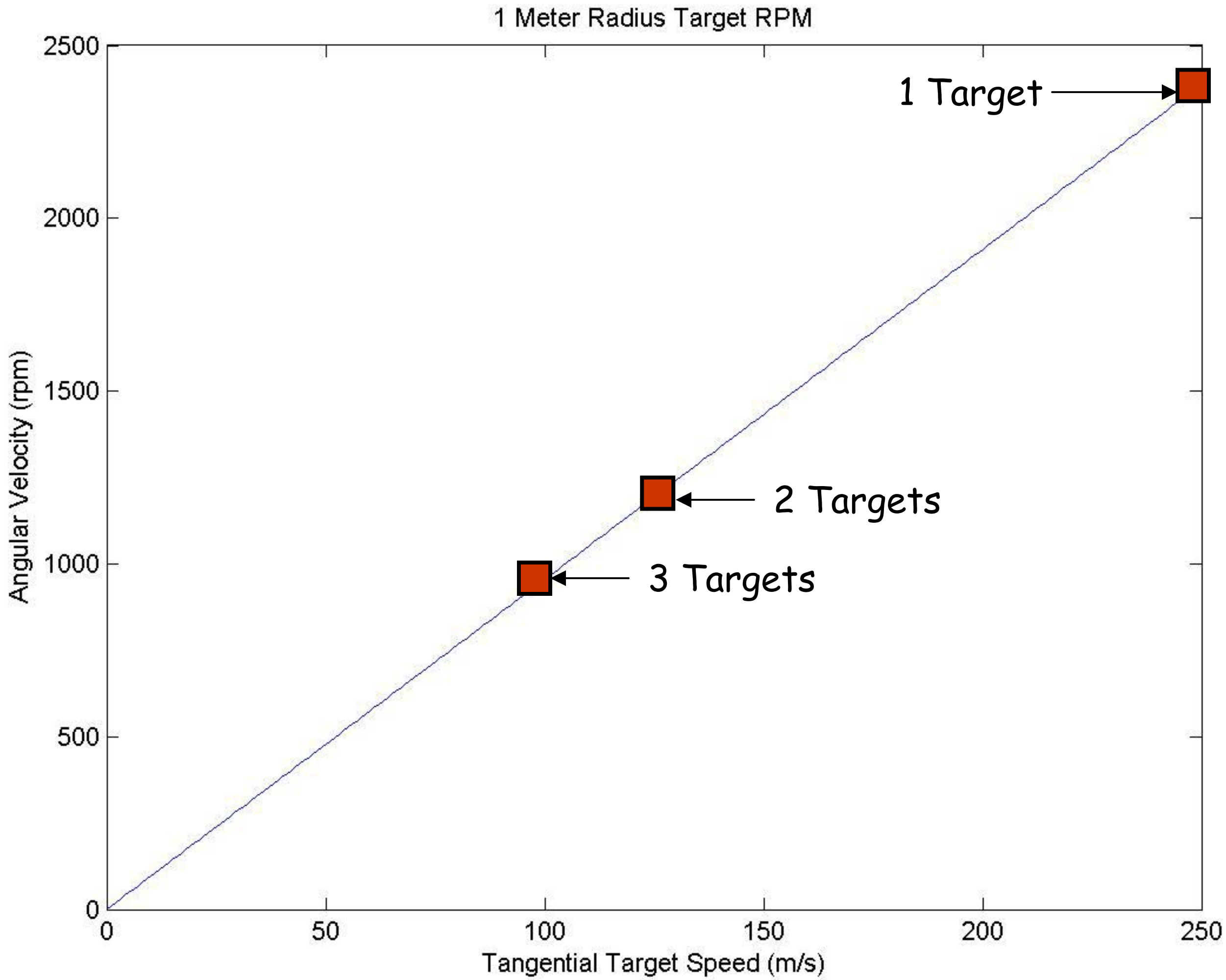
TESLA Formatted Beam (SSTS)



EGS4, BeamPath, MatLab Simulations and Calculations:

Required Rotational Speed for 1 m radius Target

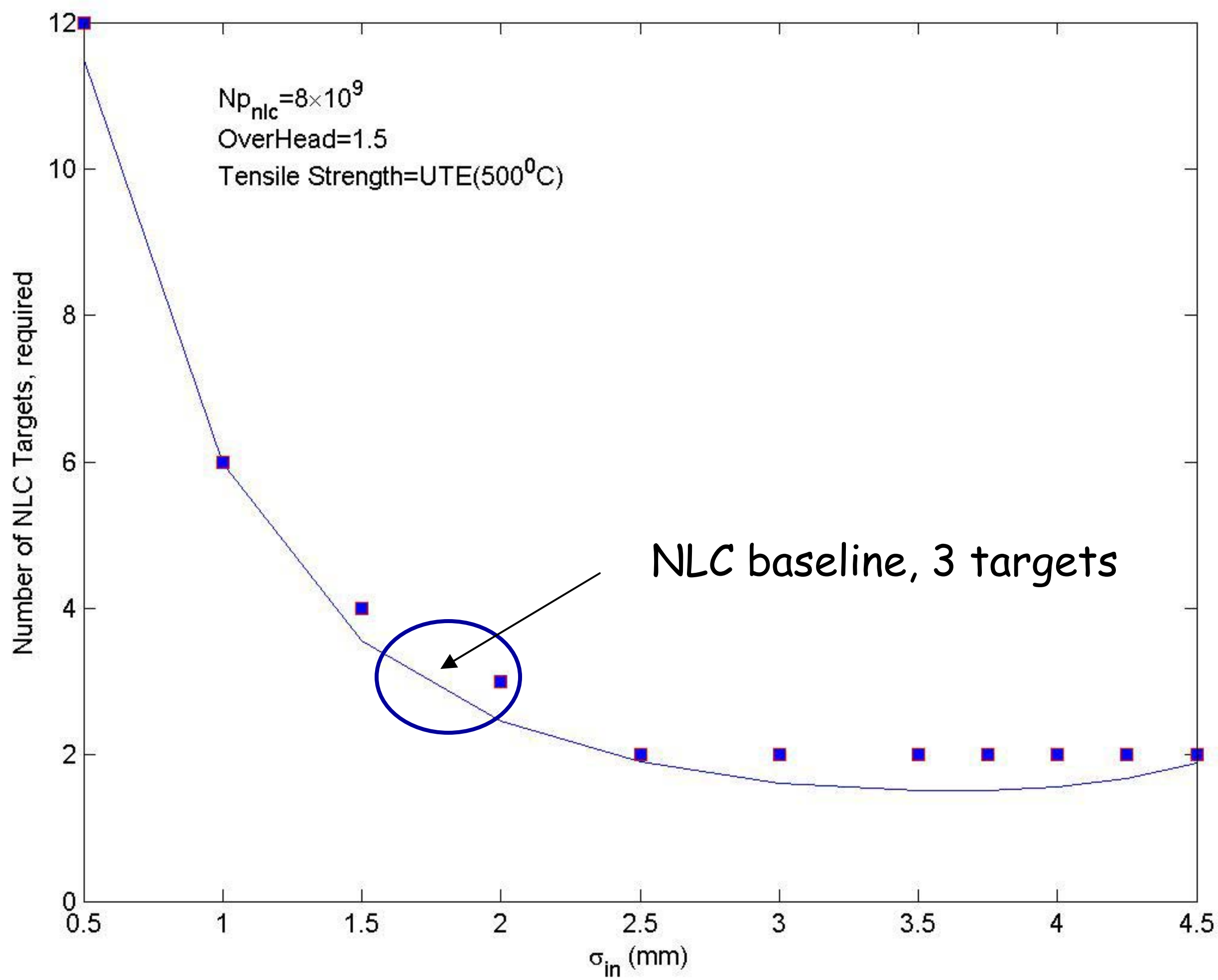
TESLA Formatted Beam (SSTS)



EGS4, BeamPath, MatLab Simulations and Calculations:

NLC Number of Drive Electrons Per Bunch

NLC Formatted Beam (Transient Shock Stress)



Undulator Positron Systems

US LC physics requirements specified by the USLCSG Physics/detector Subcommittee

- initial energy 500 GeV c.m.
- upgrade energy: at least 1000 GeV c.m.
- electron beam polarization > 80%
- an upgrade option for positron polarization
- integrated luminosity 500 fb^{-1} within the first 4 yrs of physics running, corresponding to a peak luminosity of $2 \times 10^{34} cm^{-2} s^{-1}$.
- beamstralung energy spread comparable to initial state radiation.
- site consistent with two experimental halls and a crossing angle.
- ability to run at 90-500 GeV c.m. with luminosity scaling with E_{cm}

G. Dugan, NLC Coll. 6/17/03

Undulator Positron Systems

Warm option reference design

New features of 2003 NLC configuration:

- SLED-II pulse compression
- 2-pack modulator
- 60 cm, 3% v_g HDS structures
- EM quads in linac
- Improved damping ring design
- Improved positron source
- BNL-style SC final focus doublet
- "Low-energy" IR reach improved to 1.3 TeV

Differences between the warm option reference design and the 2003 NLC design:

• The use of an undulator based positron source, utilizing the high energy electron beam at 150 GeV, instead of the conventional positron source

• At the subsystem and component level, specification changes to facilitate comparison with the cold LC option.

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Undulator Positron Systems

Cold option reference design

The major changes to be made to the TESLA design are:

- An increase in the upgrade energy to 1 TeV (c.m.), with a tunnel of sufficient length to accommodate this in the initial baseline.
- Use of the same injector beam parameters for the 1 TeV (c.m.) upgrade as for 500 GeV (c.m.) operation
- The choice of 28 MV/m as the initial main linac design gradient for the 500 GeV (c.m.) machine.
- The use of a two-tunnel architecture for the linac facilities.
- An expansion of the spares allocation in the main linac.
- A re-positioning of the positron source undulator to make use of the 150 GeV electron beam, facilitating operation over a wide range of collision energies from 91 to 500 GeV
- The adoption of an NLC-style beam delivery system with superconducting final focus quadrupoles, which accommodates both a crossing angle and collision energy variation.
- At the subsystem and component level, specification changes to facilitate comparison with the warm LC option.

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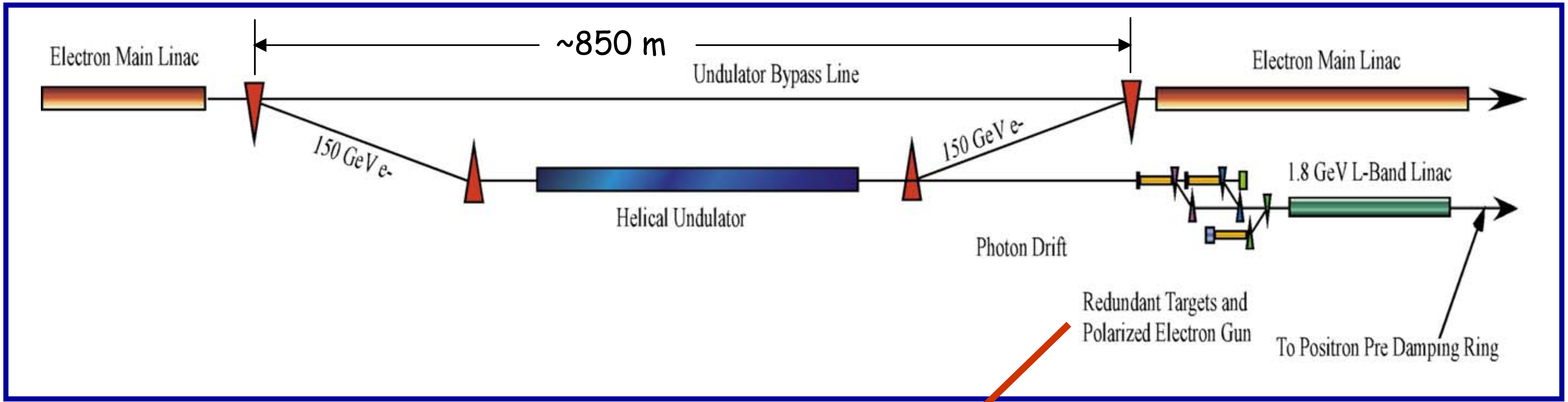
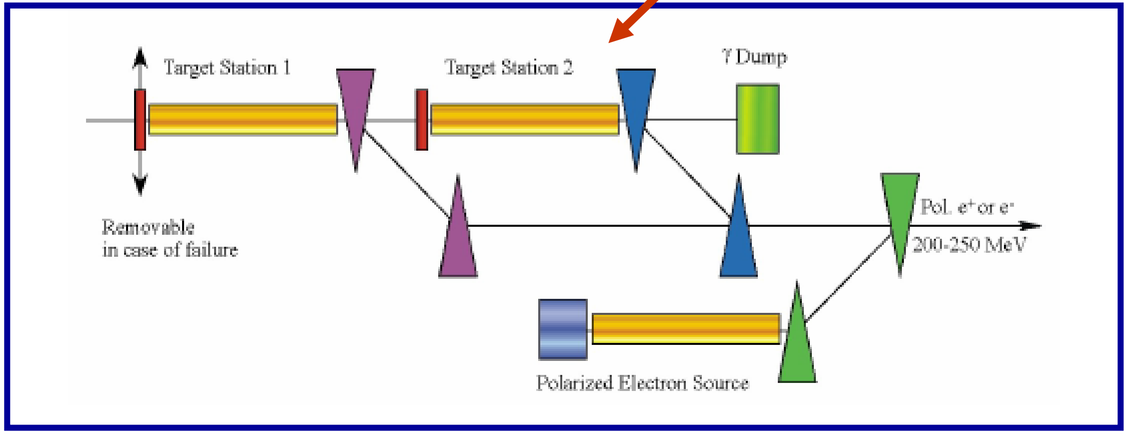
NLC/USLCSG Polarized Positron System Layout

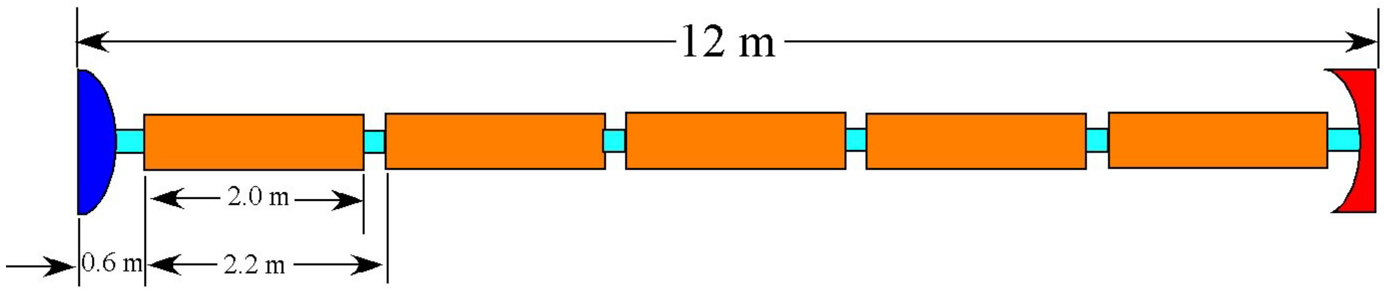


2 Target assembles for redundancy



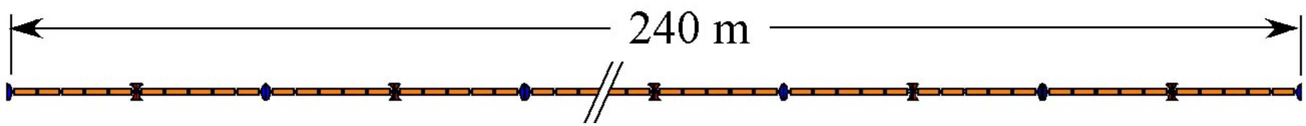
NLC/USLCSG Polarized Positron System Layout

Undulator Lattice Half Cell



[Undulator Module Parameters: Helical, K=1, λ_u=1 cm (B_0=1.07 T), ID=6-7 mm, L_u=2.0 m]

Undulator Lattice, 10 FODO Cells



Undulator-based positron system is described in USLCSG Cold Reference Design Document

Undulator-Based Positron Systems

- Idea dates back to 1979: Balakin and Mikhailichenko
- Baseline TESLA design (unpolarized)
- ALCSG P/D SC requirement for polarized positrons
- Listen to K. McDonald, next talk

e^-e^+ Sources

If it's not polarized, not interested

- Electron Sources: polarized, expected to work, lots of work left
- Conventional Positron Sources: not polarized, problems with peak energy deposition, can make a conv. System for TESLA, lots of work left
- Undulator-Based Positron Source: polarized, expect this for the LC, E-166 demonstration, lots of work left